THURSDAY, AUGUST 18, 1904.

SCIENTIFIC WORTHIES.

XXXIV.—Lord Rayleigh.

LORD RAYLEIGH'S investigations have covered so wide a field, and the advances he has made in every direction have been so marked, that it is no easy task to give an account of them in a short notice.

He has left his impress on all branches of physical research, an impress distinguished by the thoroughness and completeness of his work, by his skilful adaptation of means to ends, by a keen insight into the essentials of a problem, and by a strong grasp of the fundamental principles required for its solution.

Whether it be in his early work before the days when he held the Cavendish professorship, in the series of electrical measurements that marked his short tenure of that post, or in the discoveries made more recently in his own laboratory at Terling, these distinctive features stand out; the simplest means are selected, the devices nearest to hand adopted, but the whole procedure is directed to solving, as accurately as the conditions of the work will allow, the problem in view.

The four splendid volumes recently issued by the Cambridge University Press are a striking monument of his ability; these, with the "Theory of Sound," contain his contributions to the advancement of natural knowledge, and with their help it becomes possible to give some idea of his work.

Born on November 12, 1842, the son of the second Lord Rayleigh, he was educated at Trinity College, Cambridge, which he entered in October, 1861.

Some three years later, January, 1865, he took his degree as senior wrangler. In 1866 he was elected to a fellowship, which he held until his marriage in 1871.

The first paper in his collected works is dated 1869. His latest contribution to science was read before the Mathematical Society in June of the present year, and deals with Poisson's solution of the differential equation of wave motion.

The earlier papers are miscellaneous in character. One of the most important, on the theory of resonance (*Phil. Trans.*, 1870), appears again in an altered form as an important section of the "Theory of Sound," while a series of optical papers in the *Philosophical Magazine* for 1871, dealing with the colour of the sky, the scattering of light by small particles, double refraction, and the reflection of light from transparent matter, have long been classical.

In the first of these he proved that the intensity of the light reflected from small particles varies inversely as the fourth power of the wave-length; the third paper discusses the properties of an incompressible æolotropic ether, in which the inertia is a function of the direction, while the forces are the same as those in an isotropic medium; it appears that in such an ether the wave surface would not be that of Fresnel; it has since been shown that if the medium be not incompressible, but be such that the forces resisting compression are zero, then the wave surface is Fresnel's, but the motion is no longer in the wave front. The fourth paper of this series puts in a clear and definite manner the strict theory of reflection of waves in an elastic solid as developed by Green, distinguishing clearly between his results and those of other writers less rigid in their demonstrations.

Another series of optical papers of great importance was published in the *Philosophical Magazine* nine years later, in 1880.

These dealt with the theory of certain optical instruments, especially with regard to their separating or resolving power. In the first of these is established the fundamental law that a double line, when viewed through a telescope, cannot be fairly resolved unless its components subtend an angle exceeding that subtended by the wave-length of light at a distance equal to the horizontal aperture, and the principles leading to this law, applicable to a telescope, have been extended to the case of a microscope in more recent papers published in the *Philosophical Magazine* in 1896, and in the *Journal* of the Royal Microscopical Society, 1903.

Lord Rayleigh's contributions to optics are, however, best summed up in his article on wave theory in the ninth edition of the "Encyclopædia Britannica," and in themselves constitute a claim to the highest distinction.

Clerk Maxwell died in the autumn of 1879, and Lord Rayleigh, in response to an influential memorial, expressed his willingness to carry on the work at the Cavendish Laboratory. He was of course elected, and for the next five years devoted himself to the duties of the chair. The collected papers show us how fruitful those years were; moreover, in addition to original research, there was much to be done in organising the teaching and practical work in the laboratory. On his appointment pupils were few, and organised instruction hardly existed. Maxwell had collected a number of graduate students and inspired them with a keen love for research and investigation, but the practical classes which in Lord Rayleigh's time became so prominent a feature of the laboratory had almost to be formed. In 1879 the natural science tripos contained twenty-five names; in 1884 there were eighty successful candidates, very many of whom obtained a large portion of their training at the laboratory.

The researches of this period include the well known series of investigations into the fundamental electrical units. These were determined with an accuracy which it is difficult even after twenty years' experience of similar measurements to surpass, and have formed the foundation for the legal standards of resistance, current, and electromotive force throughout the world.

Allusion should be made to a short paper in the *Philosophical Magazine* for 1892 on a comparison of the methods for the determination of resistance in absolute measure, which, as a recent writer in these columns, in reviewing the collected papers, July 30, 1903, observed, "exhibits in a marked degree Lord Rayleigh's great capacity for seeing distinctly the essential point of an experiment or a measurement and keeping that clearly in view throughout. This indeed is a distinguishing feature of his experimental work, a main factor in his success. Those who knew the Cavendish Laboratory when the electrical measurements were going on, or have since visited the laboratory at Terling, from which no less important work is continually being published, have sometimes been astonished at the makeshift character of much of the apparatus. Contrivances of wood and wire and wax do duty where most men would use apparatus elaborated with a quite unnecessary care; but in Lord Rayleigh's case, while the essential instrument on which the accuracy of the investigation really depends is as perfect as the skill of the workman can make it, and in addition has been thought out in all its details so as to fit it best for the purpose immediately in view, for the rest the arrangement which comes first to hand is utilised without regard to appearances."

The Cambridge period came to an end in 1884, but previously to this, in his address as president of the mathematical and physical section of the British Association in 1882, Lord Rayleigh had indicated what the next series of experiments were to be. He referred on that occasion to the supposed relation between the atomic weights of the chemical elements as a subject inviting investigation, and continued, "The time has perhaps come when a redetermination of the densities of the principal gases may be desirable—an undertaking for which I have made some preparations." Two years later, when president of the association at Montreal, speaking of the value of the study of electrolysis as affording a deeper insight into the nature of chemical reaction, he remarked, "And if I might without presumption venture a word of recommendation it would be in favour of a more minute study of the simpler chemical phenomena."

From this time forward Lord Rayleigh has devoted much of his time to the work thus indicated, publishing papers in 1887 and 1889 respectively on the relative densities of hydrogen and oxygen and on the composition of water in which results are given bearing on Prout's hypothesis.

The first article in the fourth volume of the collected papers is a letter to this Journal, which begins:—"I am much puzzled by some recent results as to the density of nitrogen, and shall be much obliged if any of your chemical readers can offer suggestions as to the cause. According to two methods of preparation I obtain quite distinct values. The relative difference, amounting to about 1/1000 part, is small in itself"—the difference ultimately found was 1/200—"but it lies entirely outside the errors of experiment, and can only be attributed to a variation in the character of the gas"; and his paper concludes, "Is it possible that the difference is independent of impurity, the nitrogen being in a different (dissociated) state?" This, which was published in 1892, was the first indication of the discovery of argon.

In the following year, 1893, Lord Rayleigh communicated to the Royal Society a paper on the densities of the principal gases, containing absolute determinations with all the precautions that recent physical experience or theory could suggest. Here again he points out that nitrogen prepared from ammonia is lighter than atmospheric nitrogen by something of the order of one-half per cent.; he excludes the possibility of contamination by any known substance, which suggests, as before, that an explanation is to be looked for in a dissociated state of the nitrogen itself. In April, 1894, he returned to the problem by way of further assuring himself by experiments on actual measured contamination of the absence of known impurities, and as against the dissociation hypothesis ascertained that keeping the lighter nitrogen for eight months did not increase its density. Chemical nitrogen was shown to differ from atmospheric nitrogen. As it appeared that the impurity could not be removed by known processes, and could hardly be in the chemical nitrogen, the next step was to remove the nitrogen from the atmospheric gas. This was essayed by Lord Rayleigh by combination of the nitrogen through the agency of the electric discharge, and by Sir William Ramsay, who had become associated in the work, by passing it over heated magnesium. Both workers were able to announce to the British Association at Oxford the discovery of a residue constituting a new gaseous constituent of atmospheric air. Then followed the joint memoir of Rayleigh and Ramsay on the isolation and properties of argon.

This physico-chemical work has been since continued in various forms, the physical properties of argon and of other gases have been investigated, and in particular attention has been given to the accuracy with which Boyle's law is satisfied at the ordinary temperature. This investigation has been extended from pressures of 0.01 mm. of mercury up to 150 mm., and the research is still in progress.

In addition to this physical work, numerous mathematical papers, chiefly on problems relating to wave motion and vibrations, should be mentioned.

Meanwhile, wide as has been the field of pure science covered by Lord Rayleigh's activities, he has found time to spare for the promotion of the application of science to industry and commerce. He was a prominent member of the Board of Trade Committee on Electrical Standards, to which we owe the legal definitions of the ohm, the ampere, and the volt. He presided over the Treasury Committee which recommended the establishment of the National Physical Laboratory, and for the past five years has been chairman of the executive committee of the laboratory. To his wise counsels and guidance much of its success is due. Recently he has been a member of a Board of Trade Committee on methods of testing gas, while he is chairman of the Ordnance Committee of the War Office.

For some time he held the distinguished position of one of the secretaries of the Royal Society.

Throughout his life the search of truth in nature has been his main endeavour.

> "The works of the Lord are great
> Sought out of all them that have pleasure therein"

is the motto he has prefixed to his collected papers. His friends and pupils throughout the world hope that for many years to come he may continue as their guide in that search which he has already made so fruitful.

PHYSIQUE AND EDUCATION.

Physical Deterioration, its Causes and the Cure. By A. Watt Smyth. Pp. xv+318. (London: John Murray, 1904.) Price 6*s.* net.

Les Exercises physiques et le Développement intellectuel. By Angelo Mosso. Pp. 294. (Paris: Félix Alcan, 1904.) Price 6 francs.

MRS. WATT SMYTH'S book performs good service in directing the attention of that larger public who imagine Blue-books to be dull, and who avoid the study of health reports, to the national health. Those great weaknesses and injuries that beset the infant citizen have hitherto caused quite insufficient concern. Most of the drawbacks to healthy living here set out were proclaimed by the International Congress of Hygiene in 1891; so slow has been the progress in remedying them that we must hope these chapters will be more widely read than those transactions have been. Evidently many good sources of evidence have been carefully searched; even the sociologist may seek here for references, and while the frequent change of theme has necessitated brevity, the most salient facts and features receive due prominence.

So manifest and so important is the prevalence of physical unfitness in children, as observed first by Dr. Francis Warner, as recently reported on by a Royal Commission (making a striking contrast between the children of Aberdeen and those of Edinburgh), and as now under consideration by a Departmental Committee, that the causes and cure thereof call for this volume, whether or no a "general deterioration" be proved. The argument that excessive urban infant death rate is evidence of deterioration of survivors when illustrated by the annual mortality table of the whole of England (where up to the last decennium such mortality has declined) is an argument against so many individuals deteriorating as formerly. So "Individual Physical Deterioration" would seem a more appropriate title for this work. In any case, the comparison of the present day low expectation of life at Southwark (thirty-six years) with Hampstead (fifty years) is far more important than the consideration of the wretchedness of sixty years ago, when Whitechapel had an expectation of only thirty-one years.

Here are well told the many wants on which unfitness depends. First, in the mother, want of knowledge and want of means; in the infant, want of natural or of proper food; in the pupil, want of sufficient food. Next comes want of air, overcrowding (insufficiently defined), want of school and bedroom ventilation. Further, rest is wanting to the mother, and still more wanting to those children who labour; recreation is wanting to the children, and in the long unbroken hours of school work. Exercise is needed along with recreation.

Such are the causes of physical unfitness; cure lies in their removal. In general, two means of remedy are proposed—legislative measures and increase of instruction and knowledge. Perhaps the legislative proposals of the book evince warm-hearted suggestion rather than practical statesmanship; if there be not in these measures danger of relieving parents of their responsibility, one may yet say with Dr. Bulstrode, the State cannot move except in response to a decisively expressed public opinion, and to load the machinery of public health administration with unpopular measures is, as has been amply exemplified in the history of public health, a futile and eminently unscientific proceeding. To take a current instance; existing powers of making and enforcing by-laws on the overcrowding in the east of London are not carried out, and have not been thoroughly tried.

We welcome in this book a beginning of the other means of remedy—increased knowledge and instruction. A spread of the information here given may render possible in future legislative measures for which the nation is not yet ripe.

We agree with the writer that "the root of the national unfitness lies in the health of the mother during pregnancy and the feeding of infants during their earliest years"; and we read, "out of the children (Sheffield) under two years who had died during the summer of diarrhœa, death in 21 per cent. resulted from the inexperience or ignorance of the mothers."

The better health and physical development (and lower infantile death rate) of Jewish children Dr. Hall "attributes mainly to the fact that Jewish women are better nourished during pregnancy, are more anxious to suckle their children, are more attentive to them in early childhood and feed them with more intelligence." The Royal Commission on Alien Immigration was similarly told, "the difference in the death rate is due to the better care the inhabitants take of themselves and their mode of life," and an appendix shows death rate of infants, Whitechapel 144, Limehouse 204, Whitechapel having nearly double the overcrowding, but 31 per cent. aliens as compared to 3 per cent. in the Limehouse population. Further, while for ten years the aliens and overcrowding had been increasing in Whitechapel, infant deaths had fallen 15 per cent. In Limehouse, with no such increases, deaths had risen 7 per cent. The explanation of these striking figures lies in the fact that the overcrowding of Whitechapel is caused by aliens—for the most part Jews. No laws will remedy ignorance; let us first take the mote out of our own eye and learn a lesson from the Jewess.

Mrs. Watt Smyth has convinced us that the teaching of girls is the key of the position, and her vivid